CHEMICAL COMPOSITION OF MERIDIANI SEDIMENTS AND POSSIBLE PRECURSOR MATERIAL. J. Brückner[1], R. Gellert[2], G. Dreibus[1], and Athena Science Team[3], [1]Max-Planck-Institut f. Chemie, J.-J.-Becher-Weg 27, D-55128 Mainz, Germany (brueckner@mpch-mainz.mpg.de), [2]Dep. Physics, Univ. of Guelph, Guelph, On, Canada, [3]Cornell Univ., Ithaca, NY, USA.

Introduction: The Alpha Particle X-ray Spectrometer (APXS) onboard the Mars Exploration Rover Opportunity measured over 100 samples during its four-year journey at Meridiani Planum [1]. The samples measured by the APXS along the 11-kilometer traverse can be divided into: (1) soils that are undisturbed (as is), disturbed (by rover wheels), or spherule-covered, (2) sedimentary rocks that are undisturbed, brushed, or abraded by the onboard Rock Abrasion Tool (RAT), and (3) several 'exotic' rocks [3]. Investigating the concentration patterns of various elements as function of S content reveals possible precursor material that may have formed the S-rich sediments.

Soils and Rocks: Soils, which contain S concentrations of 1.8 to 3 weight percent, dominate the Meridiani planes. At impact craters, outcrop rocks are exposed that are of sedimentary nature [4]. In Figure 1, Si versus S is shown for two soil types and three rock surface types. The field of soils is clearly separated from the sedimentary rocks by distinctly lower S contents. The three sedimentary rock surfaces contain S concentrations ranging from 4.5 to 11.5 wt. %. The abraded surfaces always have the highest S concentration compared to their corresponding undisturbed or brushed ones.

Mixing Model: In Figure 1, the abraded sedimentary rocks are fitted by a straight line. A large correlation coefficient R of 0.95 indicates a linear relationship of Si and S. Apparently, S dilutes the major element Si and becomes a major element itself. This and other observations suggest a two-component mixing model for the formation of the sediments: a siliciclastic component provides minerals and a 'sulfur-bearing' component contributes various sulfates in an aqueous environment [2]. The extrapolation of the concentrations of the abraded rocks to low or zero S contents provides a method to estimate the original concentration in the siliciclastic end member.

A strong negative correlation with S is observed for Na, Al, Si, K, and Ti, i.e. unambiguous dilution of the siliciclastic component by sulfates. In Figure 2, straight lines are fitted for Al and K versus S with large Rs. The effect of the adhering air-borne dust can be observed. Assuming air-borne dust and undisturbed soils are chemically similar the undisturbed surfaces of the rocks are only partly covered by soil as all rocks show higher S contents than the soils. For Al-S, the straight line of the abraded rocks passes through the field of the soils and all rock surfaces follow the line. In contrast, the straight line of K-S misses the soil field by far; hence, the undisturbed rocks deviate from the line and point towards the soils. Potassium and to lesser extent Si are examples that the siliciclastic material had a different composition than the 'modern' soil.

A weaker negative correlation with S is found for P, Cr, and Fe (Figure 3). Phosphorus is clearly enriched in the rocks; the straight line misses the soil field. As Ca is weakly increasing with S (Figure 4), the speciation of P is not obvious: pure apatite should produce a line with positive slope.

In spite of a large S concentration range, Fe contents of the abraded rocks do not show a real dilution by S (Figure 3). Moreover, to keep an almost 'constant' Fe concentration additional amounts of Fe must have been added together with S, e.g. ferric sulfates. Jarosite was detected in the sediments by the Mössbauer Spectrometer [5].

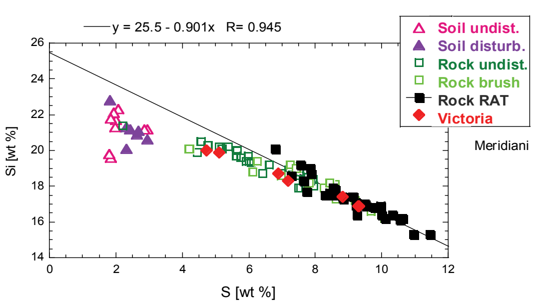

Figure 1 Concentration (weight percent) of Si versus S for natural and disturbed soils (triangle symbols) and all sedimentary rock samples with natural, brushed, and abraded surfaces (squares). All abraded rocks are fitted by a straight line. A large linear-correlation coefficient R supports the mixing model. In addition, all rock samples from Victoria crater are marked with red diamonds.

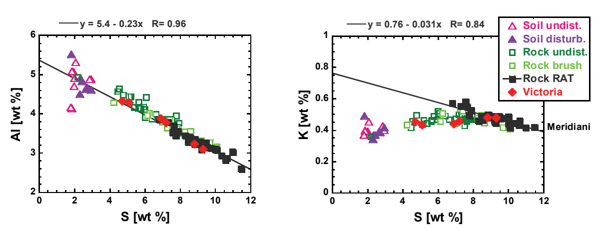

Figure 2 Concentration of Al (left) and K (right) versus S for same samples as described in Fig. 1. All abraded samples are fitted by a linear curve and good negative correlations are seen (large Rs) pointing to a dilution by sulfates.

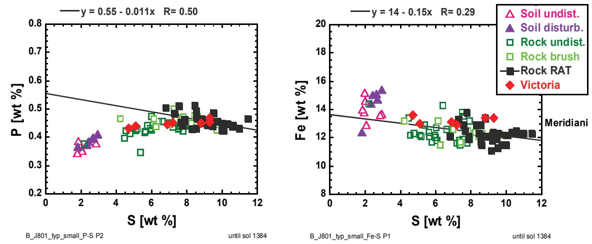

Figure 3 Concentration of P (left) and Fe (right) versus S for same samples as described in Fig. 1. All abraded rocks are fitted by a straight line.

A weak positive correlation with S is found for the two major elements Mg and Ca (Figure 4). As they are part of the siliciclastic component admixtures as sulfates have to be assumed. Restricting to the first 220 sols, which includes samples from the Endurance crater, a strong positive correlation (R= 0.9) of Mg and S is found [1]. In our mixing model, we neglect the fact of masking the siliciclastic end member concentrations by large admixtures of Mg and Ca sulfates. Consequently, a linear regression of abraded rocks underestimates the original Mg and Ca values.

Manganese versus S shows an almost flat horizontal distribution (not shown). For Cl, Ni, Zn, and Br versus S only data clouds are seen. This is remarkable as Cl and S have a positive correlation in soils.

Siliciclastic End Member: Using all abraded rocks linear regressions of all major and many minor elements can be calculated. By extrapolating to low S contents and renormalizing to 100 wt. % the composition of the siliciclastic end member can be estimated. To obtain probable ranges of elemental concentrations, S contents were varied between zero and 3 wt. %, as low amounts of S cannot be excluded in the siliciclastic component. In addition, an arbitrary amount of Cl was added (Table 1).

Gusev rocks were used for comparison with the siliciclastic material, because a large variety of different rock types were determined based on APXS measurements by the rover Spirit [6]. To obtain a proximity measure for each Gusev sample composition the Euclidean distance to each possible siliciclastic end member was calculated. Sulfur and Cl were part of the Euclidean distance in Table 1. Besides the listed samples, the following Gusev samples also show good matches: Riquelme3 (sol 1081), Madeline English (sol 1168), Superpesis (1209), or Elizabeth Emer (sol 1216). These rocks belong to moderately altered basalts found at Home Plate [7].

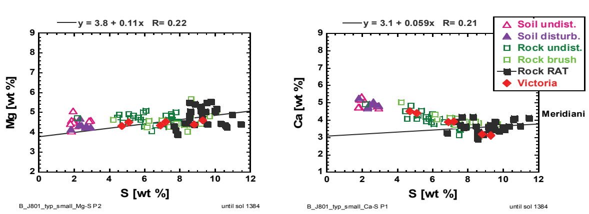

Figure 4 Concentration of Mg (left) and Ca (right) versus S for same samples as described in Fig. 1. All abraded rocks are fitted by a straight line. As weak positive correlations mean large admixtures of sulfates, the intercept of the straight line may not provide a proper estimation.

Elt.	Silicicl. #1	Esperanza Palma	Silicicl. #3	Ma-sada	Silicicl. #5	Halley Brunt Off-set2
Na	2.02	2.53	1.89	2.30	1.75	2.24
Mg	3.80	5.10	3.96	5.43	4.09	5.11
Al	5.40	4.45	5.04	5.04	4.66	5.18
Si	25.7	22.4	24.2	21.8	22.7	21.5
P	0.56	0.40	0.54	0.39	0.52	0.36
S	*0.0*	0.95	*1.51*	2.00	*2.99*	2.56
Cl	*0.0*	0.47	*0.30*	0.57	*1.00*	0.64
K	0.77	0.43	0.72	0.44	0.67	0.41
Ca	3.09	3.98	3.17	4.33	3.24	4.59
Ti	0.69	0.63	0.65	0.45	0.61	0.52
Cr	0.20	0.14	0.19	0.24	0.18	0.16
Mn	0.23	0.29	0.23	0.28	0.23	0.21
Fe	13.69	15.7	13.4	13.4	13.1	12.8

Table 1 Estimated chemical composition of three siliciclastic end members (Silicicl. #1, 3, and 5) for three assumed S and Cl contents. Three Gusev samples (measured at sol 1055, 726, and 927, respectively) are listed that have the closest compositional match based on Euclidean distance.

Conclusions: Assuming a two-component mixing model for the Meridiani sediments allows combining a siliciclastic end member with various types and amounts of sulfates in an aqueous environment to produce the observed compositions of the S-rich sediments. Extrapolated compositions of possible siliciclastic material are not basaltic, e.g. Adirondack class rocks. Elements that have large admixtures of sulfates may be underestimated in the model, such as Mg and Ca. Altered basalt samples were found at Gusev, many around Home Plate that match the siliciclastic material in composition. To find samples, whose compositions resemble the calculated siliciclastic end member, supports the two-component mixing model. Needless to say, the formation history of the matching Gusev samples may have been different from the Meridiani material. On the other hand, processes existed that produced material with similar compositions at different places on Mars and this material could have been the precursor of the Meridiani sediments.

References: [1] Brückner J. et al. (2007) in 7th Int. Conf. Mars, Abstract #3120. [2] Rieder R. et al. (2004) Science, 306, 1746. [3] Brückner J. et al. (2006) LPS XXXVII, Abstract #1882. [4] Squyres S. W. et al. (2006) JGR, 111, E12S12. [5] Morris R. V. et al. (2006) *JGR, 111*, E12S15. [6] Squyres S. W. et al. (2006) *JGR, 111*, E02S11. [7] Squyres, S. W., at al. (2007) *Science, 316*, 738.